

GETTING TO NEUTRAL

OPTIONS FOR NEGATIVE
CARBON EMISSIONS IN
CALIFORNIA

THE **NET** CARBON
INITIATIVE

Getting to Zero: *How Biomass to H₂ Conversion Can Remove CO₂ from California's Air*

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We analyzed the cost and practicality of all the negative emissions options available, **inside the borders of California**, in order to reach 125 MT/year in 2045

Three major categories were needed:

- Natural and Working Lands



25 MT/year

- Waste Biomass Conversion to Fuels with CO₂ Storage



83 MT/year

- Direct Air Capture with CO₂ Storage

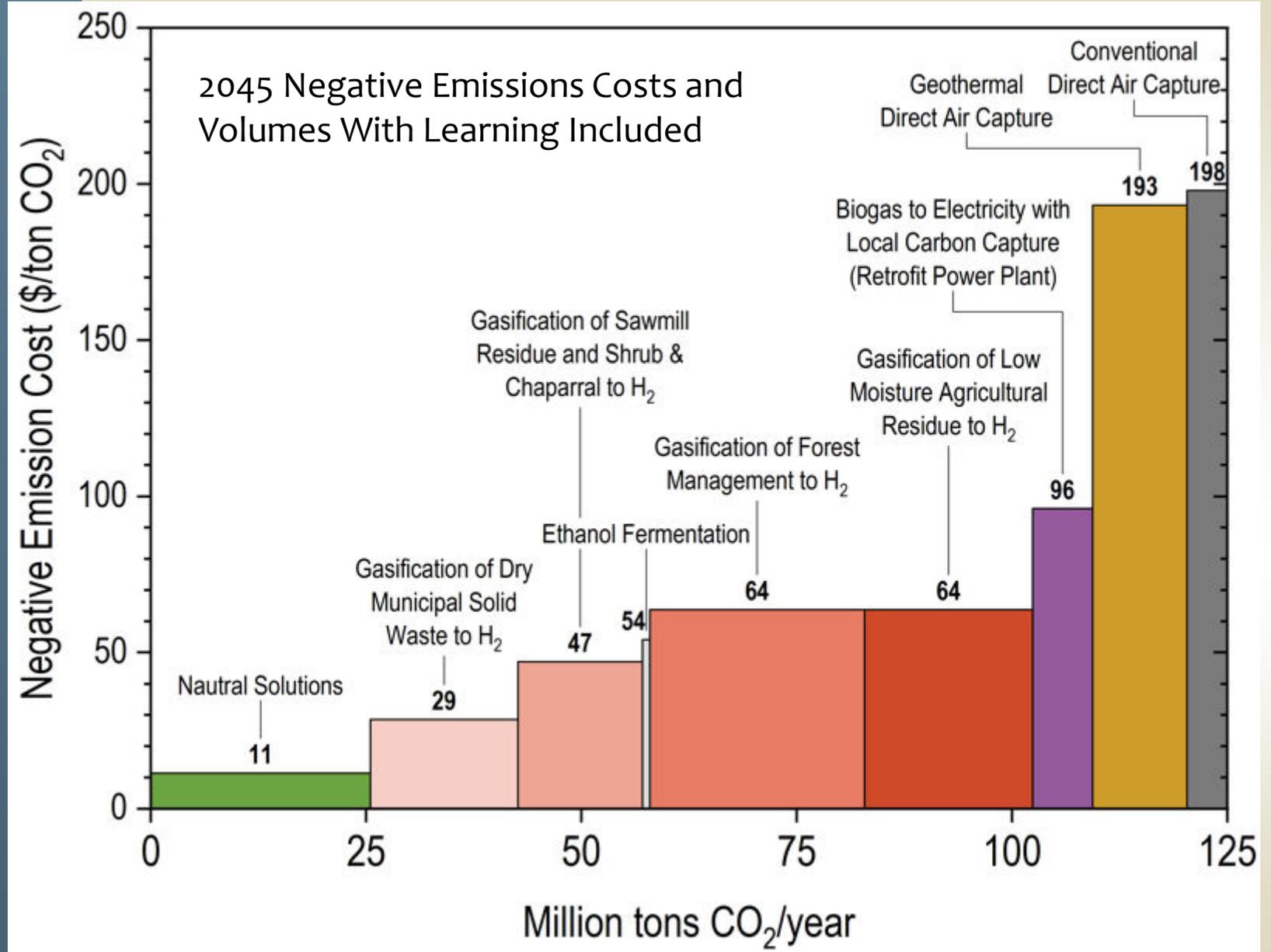


17 MT/year

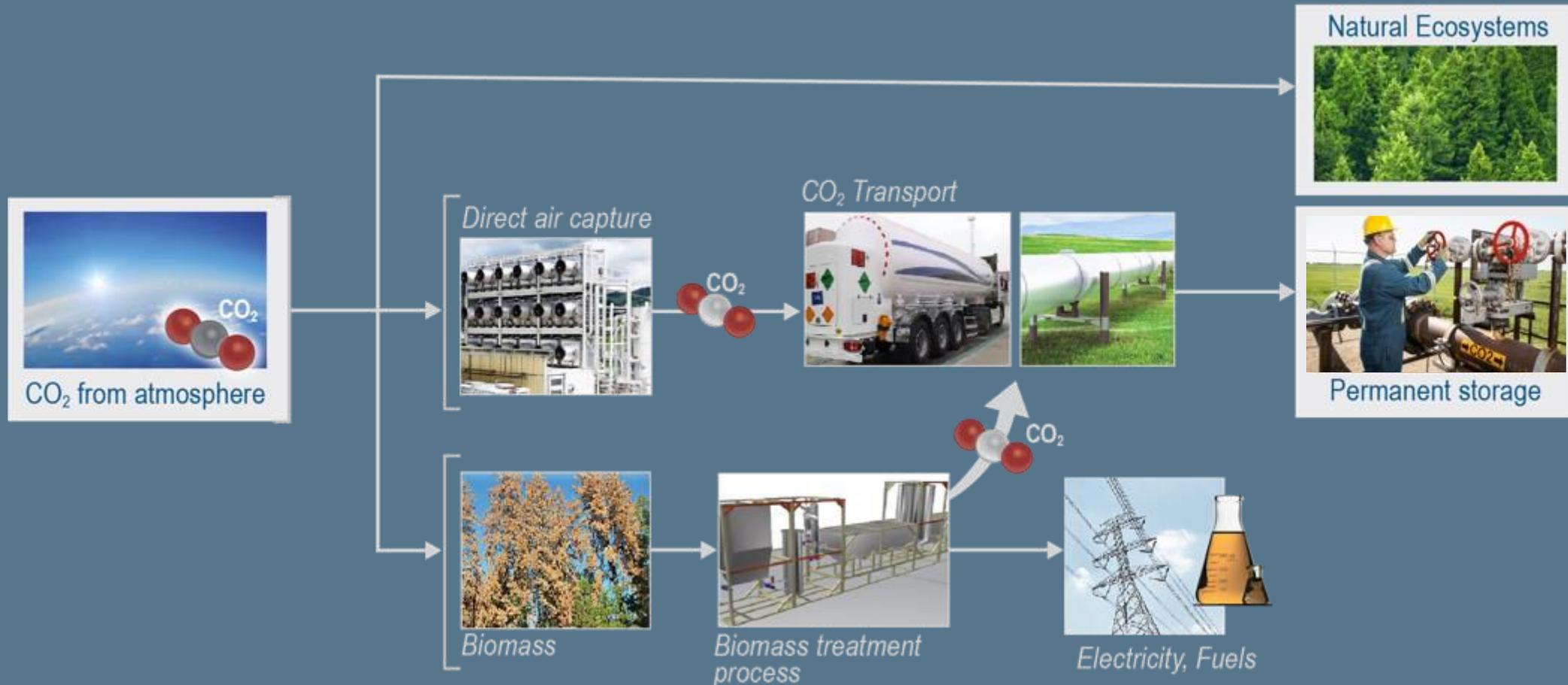
Technological readiness: mid-to-high – *no new breakthroughs required*

The least-cost path to 125 MT/year uses natural solutions, gasification of biomass to H₂, and some direct air capture.

\$8B/year levelized cost.



This is a robust set of solutions



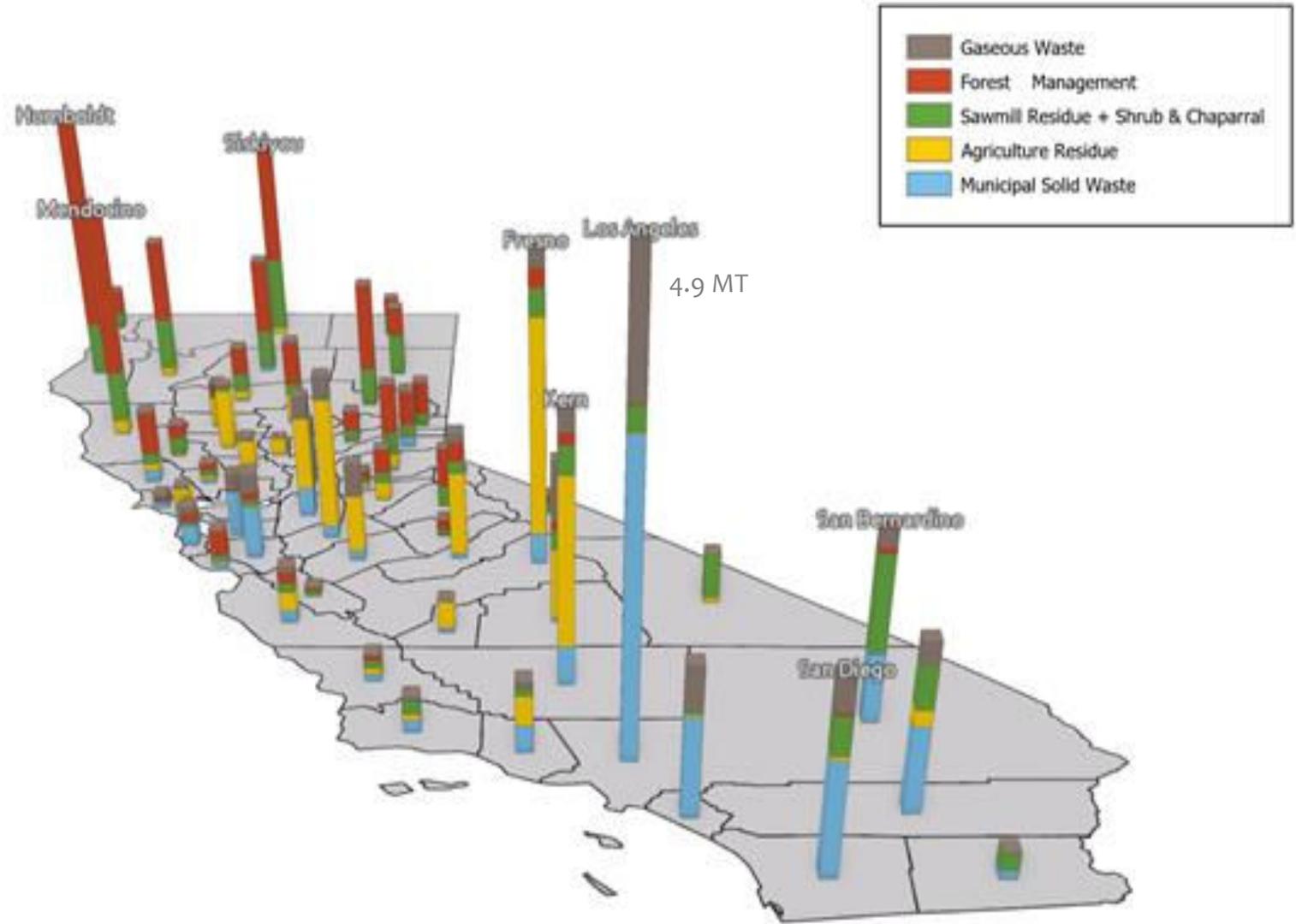
Many groups of options (50 pathways) in total cost range of \$10-\$15 B/year

Focus on Biomass Conversion

Using the Sun to do the Hard Work

Waste biomass is broadly distributed in California

- We estimate that 58 million bone-dry tons will be available from waste sources in 2045
- 100% conversion to CO₂ would yield 106 MT CO₂
- Only waste biomass considered – *no energy crops*



2019 added geologic storage to the California Low Carbon Fuel Standard

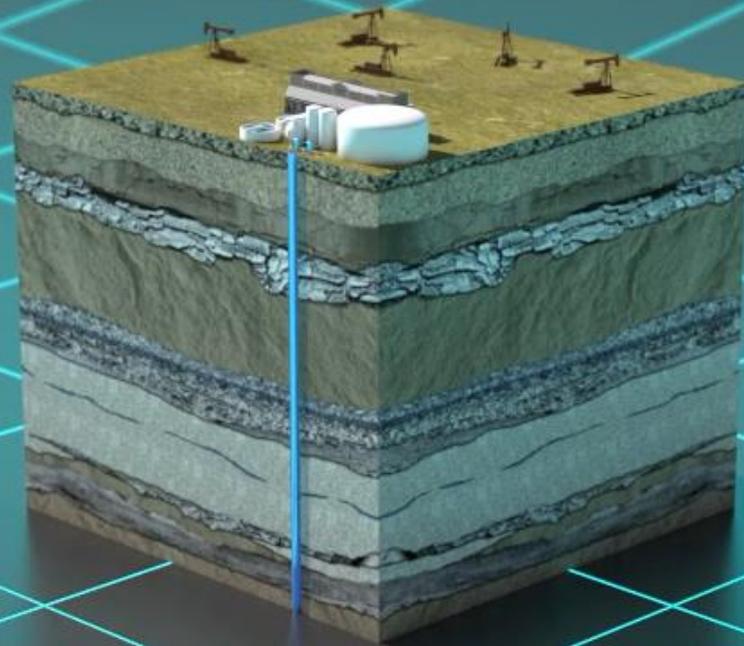
Most reductions in carbon intensity were already allowable (efficiency, renewable power, better feedstock).

Finalized for 2019, carbon capture and storage *on any process that yields a fuel sold in California* will generate a credit that can be traded or used.

The accounting and storage rules are rigorous.



Geologic Storage: Liquid CO₂ at Great Depth



Most of the removed CO₂ will have to go underground.

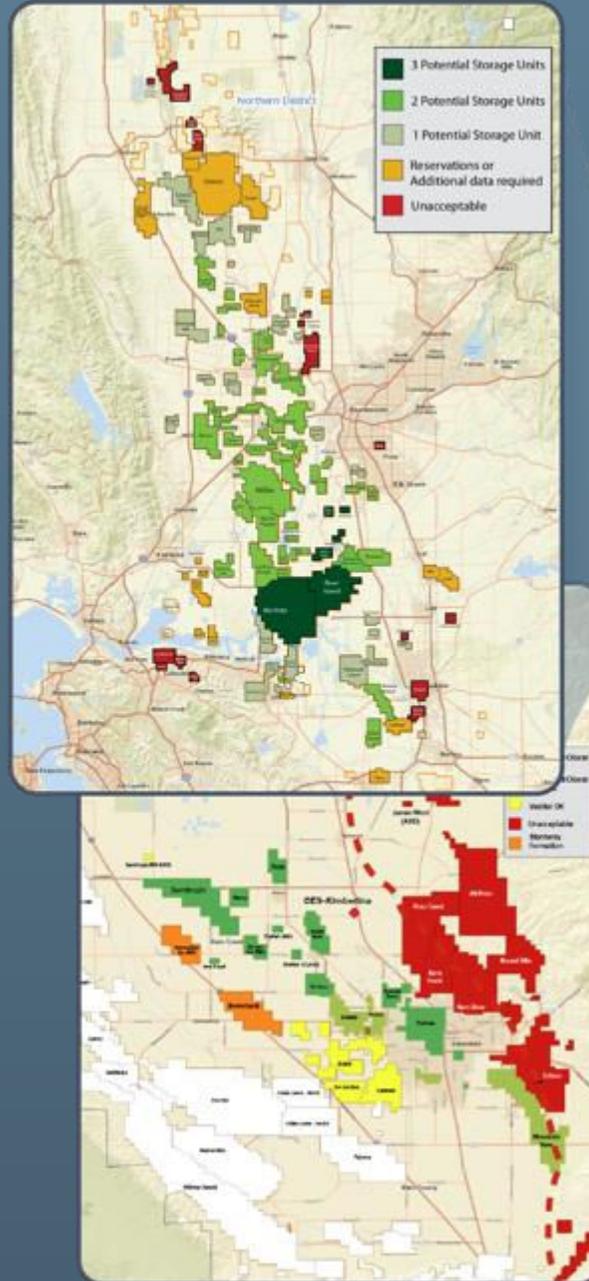
CO₂'s **properties** are very similar to oil. It can be **stored** in the same places. The **technology, people, and jobs** are the same for both.

The sunset of the oil age can also be the rise of the storage age.



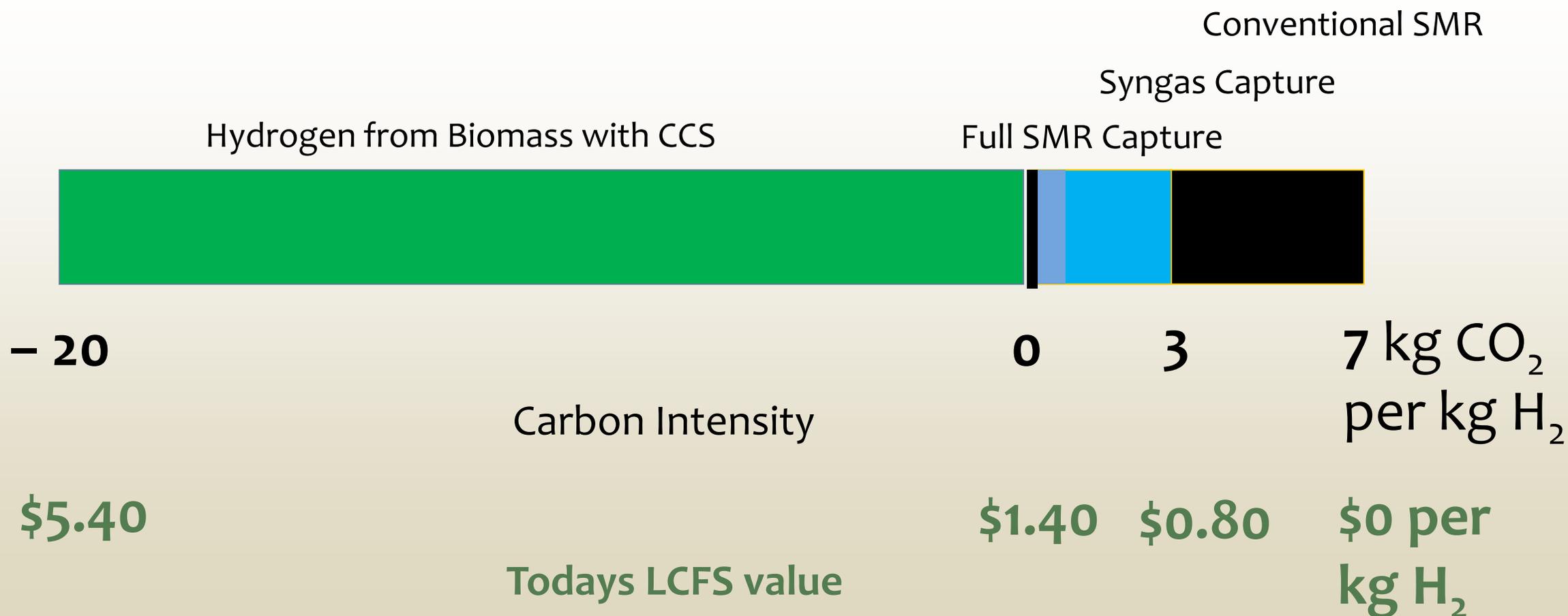
There is plenty of safe space in California to store CO₂ underground—in the same rocks that have held oil and gas for millions of years.

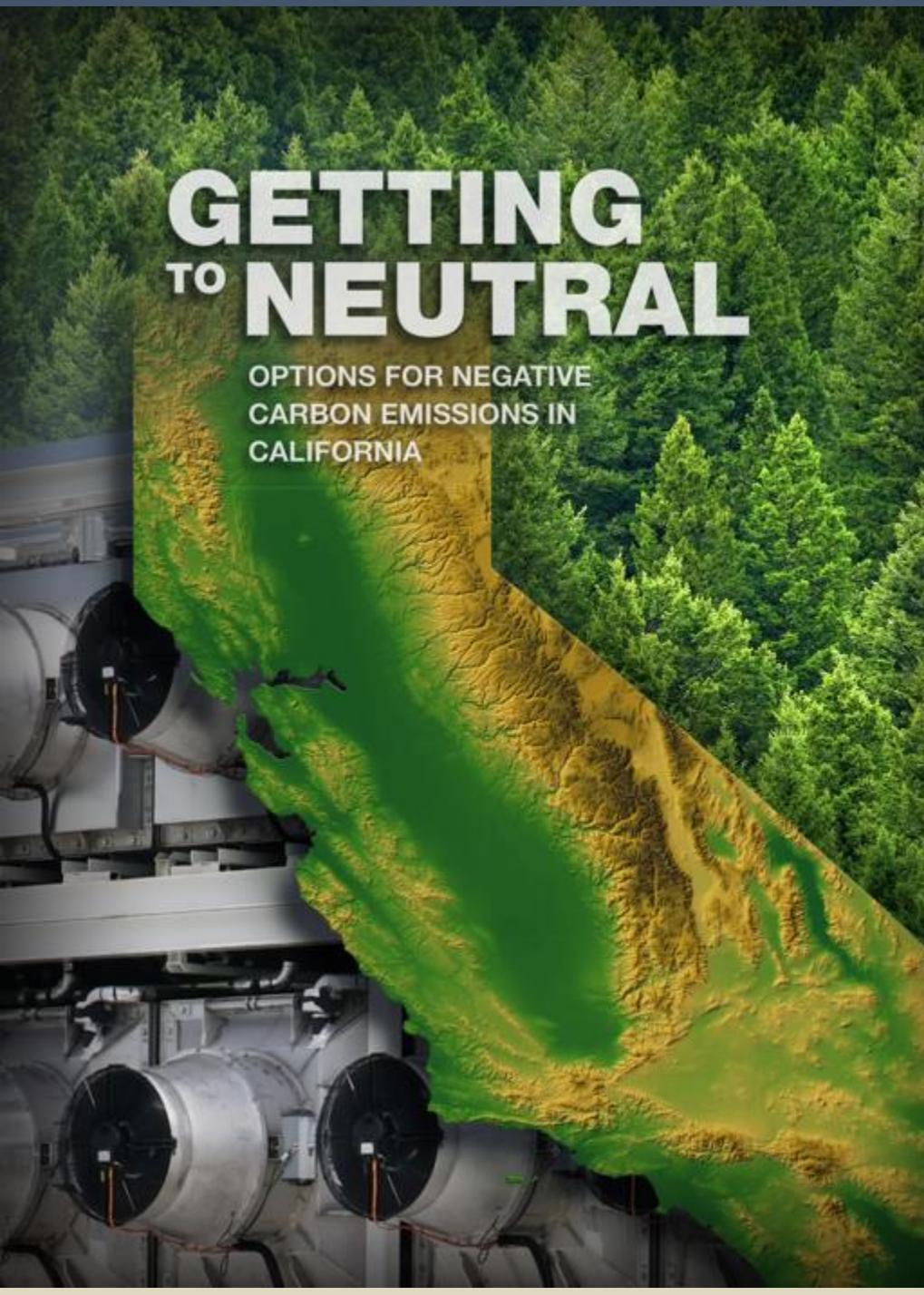
We have identified **17 billion tons** of safe storage in **just 2 areas** of the Central Valley.



Permanent geologic storage is necessary

Carbon Intensity of Hydrogen with Carbon Storage: +7 to - 20 kg CO₂/kg H₂





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- California's waste biomass could be turned into 4 million tons of hydrogen.
- 80 million tons of CO₂ could be removed from the air in the process
- Current LCFS value of \$200/ton CO₂ is more than enough to incentivize new facilities.
- This process could move biogas into the mainstream of climate technologies.

Google *LLNL Carbon Report* to download the report

https://www-gs.llnl.gov/content/assets/docs/energy/Getting_to_Neutral.pdf